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Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to testify today on the next generation of vehicle and fuels technology.

To paraphrase President Bush in his State of the Union address this year, breaking our national addiction to oil is an imperative for our time. Today, no sector of energy consumption is more in the spotlight than vehicles (cars and trucks), and the fuel that propels them. In the President's *Advanced Energy Initiative*, a broad program for developing cleaner, cheaper, and more reliable alternative energy sources and technologies, vehicle and fuels initiatives hold a central place. I would like to give you an overview of the Department of Energy's (DOE) research and development (R&D) programs in these areas, including technologies that will make a difference for today's drivers, and those that can usher in a generational change. In general, the Department supports efforts that would reduce petroleum consumption both through improved efficiency of use and through substitution of domestic alternatives to petroleum, such as biomass derived ethanol.

**Biofuels**

Biomass is the predominant clean, renewable energy source that can make a short-term impact on diversifying our liquid transportation fuels, thereby reducing our dependency on imported oil. The President's *Biofuels Initiative* aims to make cellulosic ethanol cost competitive by 2012. If successful, this research could lead to the production of biofuels equivalent to 30 percent of today's gasoline consumption by 2030. In FY 2007, the Department requested $149.7 million for EERE's Biomass program. The additional impetus created by the President's *Biofuels*

*Initiative* will enable program RD&D to accelerate the development and deployment of cost-competitive, bio-based liquid transportation fuels.

The program's research focus is in three areas: Feedstock Infrastructure, for reducing the cost of collecting and preparing raw biomass, and for the sustainable production and delivery of future energy crops; Platforms R&D, for reducing the cost of outputs and byproducts from biochemical and thermochemical processes; and Utilization of Platform Outputs, for developing technologies and processes that utilize intermediates such as sugars and syngas to co-produce fuels, value-added chemicals and materials, and heat and power. The program's strategy is to integrate those technologies and processes in biorefinery configurations that industry will validate at an industrial scale. We ultimately envision the development of biorefineries that will produce transportation fuels along with value-added chemicals and materials, and/or power from non-conventional, low-cost feedstocks such as agricultural and forest residues and other biomass.

For the near-term, the program supports expansion of the existing biofuels industry by helping current producers become the early adopters of our advanced cellulosic conversion technology. The leveraging of the technology through the use of the existing plant and delivery infrastructure should enable earlier deployment. The deployment is supported by our current cost-shared projects, and we plan to continue this support.

The mid term expands the Government's focus in two important ways. The first is meeting the President's objective of cost competitive cellulosic ethanol by 2012. The Department is accelerating research and development efforts to continue to reduce the barriers to cost

effectiveness. Second, we will continue to work with industry to apply that research and reduce the capital, operating costs, and risks associated with these future facilities. Deployment may be initiated in the further expansion of the existing industry and through niche opportunities ultimately leading to sustainable biorefineries.

EERE's Biomass Program's long-term focus is on further reducing the cost of producing domestic biofuels by continuing to develop advanced technologies to transform the Nation's domestic biomass resources into affordable biofuels, biopower, and high-value bioproducts. Working with the U.S. Department of Agriculture (USDA), the program leads a multi-agency initiative that coordinates and accelerates all Federal bioenergy R&D in accordance with the Biomass Research and Development Act of 2000. The long-term objectives require the development of the feedstock and the associated infrastructure discussed by the USDA and DOE in their jointly published "Billion Ton Study" report. It is anticipated that feedstock development will be the culmination of regional feedstock development efforts leading to cost-effective collection and use of agricultural and forest residues as well as regionally indigenous energy crops, such as switchgrass in the South Central region and willow in the Northeast. Research efforts combined with limited, targeted demonstrations to further focus research efforts should continue to lower conversion costs leading to the growth of the biofuels industry.

**Vehicle Technologies**

The Department presently addresses near, middle and long-term vehicle technology outcomes with two cooperative Government/industry activities: the FreedomCAR and Fuel Partnership

(where CAR stands for Cooperative Automotive Research) and the 21st Century Truck Partnership.

The FreedomCAR and Fuel Partnership is a collaborative effort among the U.S. Council for Automotive Research, five energy companies, and DOE for research on advanced automotive technologies that may possess significant potential to reduce oil consumption. The National Research Council of the National Academies published a 2005 report on the research program of the partnership, describing it as "an extremely challenging program, whose ultimate vision involves a fundamental transformation of automotive technologies and the supporting fuel infrastructure." The report went on to say that "the committee believes that research in support of this vision is justified by the potentially enormous beneficial impact for the nation."

Activities in FreedomCAR focus on the technical challenges of advanced and high-efficiency vehicle technologies, such as fuel cells, advanced combustion engines and enabling fuels, hybrid and plug-in hybrid vehicle systems (including high-power and high-energy batteries, power electronics, and motors) and light weight materials. Hybrid technologies can lead to near-term oil savings when used in advanced combustion hybrid electric vehicles; they are also the foundation for the hydrogen fuel cell hybrid vehicles of tomorrow. The requested 2007 funding level of $166 million for EERE's FreedomCAR and Vehicle Technologies Program fully supports the FreedomCAR and Fuel Partnership goals.

In support of the President's *Advanced Energy Initiative*, the Vehicles Technologies program requests $31 million, an increase of 27 percent, for advanced battery technology research.

Advances in battery and other technologies can help accelerate development of “plug-in” hybrid electric vehicles. It is anticipated that plug-in hybrid electric vehicles should look and perform much like regular cars, but have a high energy battery that can be charged from an electrical outlet. Plug-ins would run on the stored energy for much of a typical day's driving -- depending on the size of the battery -- up to 40 miles per charge, satisfying the daily commuting needs of many Americans. In fact, some analysts say that a 40 mile battery range would allow substitution of electricity for petroleum in up to two-thirds of all miles driven by average Americans.

Most of the goods we consume cover part of their journey to us by truck. The 21st Century Truck Partnership involves key members of the commercial highway vehicle industry such as truck equipment and engine manufacturers, along with three other Federal agencies. The R&D centers on improving the efficiency of large combustion engine and fuel systems, while reducing “parasitic” losses (such as wind resistance and rolling resistance) to decrease the overall fuel consumption of highway freight transportation.

Other activities focus on accelerating the adoption of alternative fuel and advanced technology vehicles, deployment of alternative fuel infrastructure, and expansion of advanced vehicle fleet evaluations to include plug-in hybrids. There are three activities -- regulatory and rulemaking support for the Energy Policy Acts of 1992 and 2005, alternative fuel and fleet activities, and Clean Cities -- that work to accelerate alternative fuel infrastructure installation. Clean Cities promotes deployment of vehicle technologies and alternative fuels that can reduce petroleum consumption. Advanced Vehicle Competitions provide educational opportunities for university

students to learn and use real-world engineering skills while demonstrating the performance of advanced vehicle technologies. We think of these competitions as building the next generation of automotive engineers. A couple of years ago the Department found that 60 percent of graduating seniors that had participated in one of these competitions were hired by an automaker or one of the major automotive suppliers. Next week students from 17 university engineering departments will face off in the second round of the Challenge X competition at GM's Desert Proving Grounds, and see who has done the best job of improving the fuel economy and emissions of a Chevy Equinox while maintaining vehicle comfort and capabilities. GM is our headline co-sponsor this year, but they are joined by over 30 corporate sponsors from the supplier community.

Near-term activities also include developing and deploying bio-fuels to displace petroleum. This year, we will spend at least $3 million to provide assistance for fueling stations to add E-85 capabilities. Depending on the results of a solicitation out right now (closing June 8), the total committed to E-85 deployment could reach $4.5 million. And each DOE dollar will be leveraged by cost-share from the private sector or state and local governments. Through on-going discussions with automakers, the Department is encouraging increased production of flex fuel vehicles. The Department is also working with the National Biodiesel Board to tighten fuel standards and to develop real-time fuel quality tests for biodiesel to enhance performance in advanced engines. Advanced catalysis research at our National Laboratories could enable more efficient diesel engines to replace gasoline engines in light duty vehicles without sacrificing air quality.

In the mid-term, advanced combustion research seeks to use electronic controls and new fuel formulations to operate compression ignition engines in the zone between soot formation and nitrogen oxide formation. Research success in homogeneous charge compression ignition (HCCI) and other low temperature combustion regimes could result in passenger vehicles greater than 40 percent more fuel efficient than today's best gasoline cars. Additional gains are possible since advanced combustion engines will still generate waste heat. One of our most tantalizing research opportunities is the direct conversion of waste heat to electricity using solid state thermoelectric devices. Our 2007 budget request commits over $3 million to solid state thermoelectric research.

Research on hybrid electric vehicle (HEV) technologies (batteries, power electronics, motors), addresses reduced component cost, improved performance, and extended lifetimes. Efforts are being expanded to include technologies that would enable plug-in HEVs. Materials research emphasizes new processes to make raw carbon fiber cheaper, and allow carbon fiber parts to be manufactured at speeds appropriate for automotive mass production. Use of carbon fiber parts, along with magnesium, titanium and lightweight steel alloys would enable fabrication of lighter vehicles that use less fuel while maintaining occupant safety and comfort. We are also examining new processes for recycling these vehicles in our pilot recycling facility at Argonne National Laboratory. Research focused on advanced batteries, power electronics, motors and lightweight materials is essential for improved hybrid electric vehicles in the near- and mid-term as well as fuel cell hybrid electric vehicles in the long-term.

**The Hydrogen Frontier**

Now that I've discussed the near- and mid-term options for reducing foreign oil dependence, I'd like to move on to hydrogen, which offers a strategy for long-term energy security and reduced emissions. Hydrogen is a transportation fuel that can be made from a variety of domestically available resources, while removing criteria pollutants and carbon from the tailpipes of vehicles. The Department's research explores pathways to manufacture and deliver hydrogen from fossil, nuclear and renewable resources.

The FY 2007 Budget requests $289.5 million for the President's Hydrogen Fuel Initiative, including $195.8 within the Office of Energy Efficiency and Renewable Energy. The balance is requested in our basic science, fossil and nuclear offices, as well as the Department of Transportation. We are closely coordinating our efforts with other Federal agencies through a special task force led by the Office of Science and Technology Policy.

The Department is pleased to have Congress' support of the hydrogen program in Title VIII of the Energy Policy Act of 2005. The requirements in the Act are consistent with the Department's plans and include important provisions for coordination of efforts across the Federal Government and for independent advice from outside the Department on our hydrogen efforts.

Indeed, much progress has been made since 2003 when President Bush committed $1.2 billion over five years to accelerate hydrogen research. Since then, the Department's program has been twice reviewed by the National Academies. In the latest review released last summer, the chair

of the review committee said the program "is making significant headway" and that "it could have an enormous beneficial impact on energy security and the U.S. economy."

Our hydrogen program is focused on research to overcome the technology barriers that would be a precondition to broad commercialization. Over three years, our ongoing research has contributed to reducing the high-volume cost of automotive fuel cells from $275 per kilowatt in 2002 to $110 per kilowatt in 2005[1]. Further research and development are required to meet our ultimate cost target of $30 per kilowatt. In FY 2007, the Department will initiate new projects in several areas, including improved fuel cell membranes, cold-weather start-up and operation, and the effects of impurities on fuel cells. In addition to supporting fuel cell cost reduction, this work will help us achieve our durability target of 5,000 hours which equates to the vehicle lifetime required.

Hydrogen storage on board a vehicle to meet all performance and cost requirements is one of the most technically challenging barriers we face. The Department has a diverse portfolio through three Centers of Excellence as well as independent projects both in applied and basic science with a total of about 40 universities, 15 companies and 10 Federal laboratories.

In just one year we are starting to see promising results with some completely new materials being developed in different areas such as metal hydrides, chemical hydrides, and carbon-based materials. Some of these materials can store 6 to 9 percent by weight of hydrogen. This is up from a maximum of 5.5 weight percent a year ago. Another step taken is to tailor these materials for storing and releasing hydrogen under practical temperature and pressure conditions.

[1] Cost Analysis of PEM Fuel Cell Systems for Transportation, September 30, 2005, Carlson, E.J., et.al., Tiax, LLC

Further research breakthroughs on materials and systems engineering is required to meet our system target to provide consumers with a 300-mile driving range. The Department's basic research is carefully coordinated with our applied research in materials development for hydrogen storage.

We are also analyzing transition scenarios on how the Nation might initiate hydrogen production and delivery infrastructure investment during the early years of potential vehicle market penetration and growth.

Working with our nuclear and basic science offices, we are pursuing revolutionary approaches to hydrogen production. For example, heat from nuclear reactors or solar energy can be used to split water into hydrogen and oxygen. This approach involves thermochemical cycles that are still under development. Other high risk, high pay-off production approaches also involve harnessing the huge potential resource of solar energy. Working with the DOE Office of Science, we are developing "photobiological" hydrogen production where micro-organisms produce hydrogen and "photoelectrochemical" hydrogen production where solid state devices use photon energy to convert water into hydrogen and oxygen.

In our coal-based hydrogen program, we plan to scale up membrane reactors for separating hydrogen gas and carbon dioxide streams. This research is closely coordinated with our FutureGen effort to create the world's first near zero-emission fossil fuel plant by using clean coal technology and sequestering of greenhouse gas emissions.

In our nuclear-based hydrogen program, we plan to complete the assembly and preliminary testing of a laboratory system to demonstrate hydrogen production by using nuclear heat to drive chemical cycles, just discussed, that split water to produce hydrogen and oxygen. In another approach, we plan to demonstrate hydrogen production from a higher temperature electrolysis system that can be more efficient than electrolyzers used today in standard industry practice.

Through cost-shared partnerships with the automotive and energy industries, four teams are installing hydrogen refueling stations and putting cars on the road to test the technology in real-world conditions as part of the Department's Learning Demonstration. Data collected on vehicle performance, durability and fuel economy is feeding back into our research program to ensure our research is focused on the most relevant problems.

As mentioned, hydrogen is critical to our Nation's long-term strategy for energy and environmental security. Developing hydrogen technologies that can be manufactured domestically will improve our economic competitiveness as well. Our manufacturing research and development effort is new in FY 2007 and will address the need for high-volume manufacturing processes for components like fuel cells that are currently hand-built. These processes are important to lowering the costs of fuel cells and to developing a supplier base. Establishing an early supply base for fuel cell applications such as portable, stationary, remote and emergency backup power lays the groundwork for much larger supply chains needed for automotive applications. In January, Secretary Bodman released a draft roadmap for public

comment on manufacturing research for the hydrogen economy. This roadmap is being finalized and will be the foundation for executing this important research.

Investments are not only occurring in the Federal Government but also at the state and local level. From Aiken, South Carolina, to Sacramento, California, hydrogen research facilities and infrastructure investments show a commitment to hydrogen and may provide the earliest catalysts for a hydrogen economy. These diverse investments increase our probability of success in solving technology barriers that would enable industry to make fuel cell vehicles that consumers will want to buy and to invest in hydrogen refueling infrastructure that is profitable. These investments can ultimately help displace demand for oil and reduce greenhouse gas emissions.

## Conclusion

Our national pathway to a secure energy future will be composed of a variety of invaluable components, from making today's internal combustion engines more efficient to developing home-grown biofuels, plugging in our cars, and harnessing the renewable, pollution-free potential of hydrogen. Working with our indispensable partners in the academic community, at our National Labs, and in private industry, we are putting our research dollars in the most promising areas to address critical technical barriers, and I believe, with confidence, that the next generation of vehicles and fuels is already in sight.